Technical Report 794

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Device-Based Gunnery Training and Transfer Between the Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT)

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Bob G. Witmer

ARI Field Unit at Fort Knox, Kentucky
Training Research Laboratory

U. S. Army
Research Institute for the Behavioral and Social Sciences

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT) were used to crosstrain soldiers from an M60A3 armor unit as M1 tank gunners. Estimates of measurement reliability were obtained for each device and the effectiveness of the devices for training gunnery skills was evaluated. Measures of effectiveness included performance improvement on each device as a function of practice on that device and training transfer between the devices. The results showed that gunnery performance could be reliably measured on both the VIGS and UCOFT. (Continued)

ARI Technical Report 794

20. Abstract (Continued)

Significant improvements in gunnery performance were obtained with both devices, but skills learned did not transfer from one device to the other.

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Device-Based Gunnery Training and Transfer Between the Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT)

Bob G. Witmer

ARI Field Unit at Fort Knox, Kentucky
Donald F. Haggard, Chief

Training Research Laboratory
Jack H. Hiller, Director

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

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FOREWORD

The Fort Knox Field Unit of the Army Research Institute maintains a program of research in Armor training and continually seeks new techniques to improve training critical skills. Gunnery skills are among the most critical and the most difficult to train and evaluate. Developing expertise in gunnery requires extensive practice with feedback about performance. Using tanks to train tank gunnery is both time-consuming and expensive. Measuring gunnery performance on tanks is difficult, as is providing accurate and timely performance feedback. Gunnery training devices, with their easy accessibility and built-in feedback and performance measurement capabilities, offer an attractive alternative to traditional gunnery training techniques. This investigation assessed the effectiveness and compatibility of two tank gunnery simulators, the Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT).

The research was conducted as part of a program that investigates the use of computer-based simulation, in accordance with a memorandum of understanding (May 1984) between the Army Research Institute and the Defense Advanced Research Projects Agency (DRPA), entitled, "Transfer of Technology of the 'Battlesight' Project and the Simulation Networking (SIMNET) Project."

Plans for, and progress on, this project have been disseminated in briefings to the Assistant Commandant, Technical Director, and Department Heads of the U.S. Armor School at Fort Knox. The research results have been provided to the heads of the Operations Research Analysis Branch and the New Systems Training Division of the Directorate of Training and Doctrine (DOTD) at the Armor School.

This research provides information on the training effectiveness and skill transfer between VIGS and UCOFT. The information can be used to select and integrate training devices into gunnery training programs.

EDGAR M. JOHNSON
Technical Director

DEVICE-BASED GUNNERY TRAINING AND TRANSFER BETWEEN THE VIDEODISK GUNNERY SIMULATOR (VIGS) AND THE UNIT CONDUCT OF FIRE TRAINER (UCOFT)

EXECUTIVE SUMMARY

Requirement:

Rising ammunition costs, difficulties in conducting live-fire exercises and new simulation capabilities have led to an increased use of simulators as training devices in training tank gunnery skills. The Directorate of Training Developments (DOTD) at Fort Knox has proposed a training program that employs a mix of training devices to be used in conjunction with live-fire exercises for training gunnery skills. The Videodisk Gunnery Simulator (VIGS) would be used to train gunners to engage targets from a stationary tank and substitute for the training now provided in the early portions of the annual gunnery training cycle. The Unit Conduct of Fire Trainer (UCOFT) would train the tank commander and gunner to coordinate their actions in performing stationary and moving platform gunnery, and would replace the later portions of the annual gunnery training leading up to the live-fire exercises that armor crews must successfully complete in order to qualify. The VIGS training would precede UCOFT training, which, in turn, would precede live-fire training. Gunnery skills should improve as soldiers progress from VIGS to UCOFT to live-fire. No data exist, however, to suggest that training on the VIGS leads to improved performance on the UCOFT, or vice versa. This research was designed to determine if practice on one device leads to improved performance on the other, in order to provide support for using a VIGS-UCOFT device mix in gunnery training.

Procedure:

Twenty-four soldiers with no previous M1 gunnery experience were divided into two groups of 12 and trained in succession to engage targets on each of two gunnery training devices. One group of soldiers was initially trained as gunners on the VIGS and then tested on the UCOFT. The other group received UCOFT training first followed by testing on the VIGS. On each device, each soldier engaged 54 single moving targets from a simulated stationary tank. Engagements presented on the VIGS were similar, but not identical to those presented on the UCOFT. During the training, an instructor operator provided feedback to soldiers on their performance and instructed them on procedures and techniques as needed.

Measures of speed and accuracy were recorded for each engagement, and performance improvement was charted for each device. The extent that performance on one device would predict performance on the other device was estimated by correlating soldier scores on the two devices. The degree to which prior learning on one device affected subsequent performance on the other device (i.e., training transfer) was also estimated.

Findings:

Naive soldiers learned to perform device-based gunnery functions as demonstrated by significant performance improvements on each device. Larger performance improvements were obtained on the UCOFT than on the VIGS, perhaps because of the lower initial levels of performance on the UCOFT. Significant correlations between UCOFT and VIGS performances were obtained, indicating that performance can be predicted from one device to the other. Despite the demonstrated predictive relationship between VIGS and UCOFT performance, prior training on VIGS did not result in increased performance levels on UCOFT. Nor did prior training on UCOFT lead to improved performance on VIGS. The failure of skills learned on one device to transfer to the other may have been due to insufficient practice on the first device or may have resulted from fundamental differences in the responses required on the prototype VIGS and UCOFT.

Utilization of Findings:

This report specifies guidelines for conducting transfer of training research on gunnery training devices. The results suggest that both VIGS and UCOFT are effective in training device-based gunnery skills, but do not support the notion that skills learned on one device lead to improved performance on the other. A short period of training on the VIGS does not appear to enhance performance on the UCOFT; therefore a training program incorporating a VIGS-UCOFT device mix may not produce the desired levels of gunner proficiency. The information presented in this report should be useful to the Army researchers responsible for evaluating training devices and to training managers responsible for making device acquisition and utilization decisions.

DEVICE-BASED GUNNERY TRAINING AND TRANSFER BETWEEN THE VIDEODISK GUNNERY SIMULATOR (VIGS) AND THE UNIT CONDUCT OF FIRE TRAINER (UCOFT)

CONTENTS

DEVICE-BASED GUNNERY TRAINING AND TRANSFER BETWEEN THE VIDEODISK GUNNERY SIMULATOR (VIGS) AND THE UNIT CONDUCT OF FIRE TRAINER (UCOFT)

INTRODUCTION

Gunnery Training and Training Devices

Advances in technology are resulting in weapon systems that are capable of inflicting massive damage on enemy forces. The effectiveness of these weapon systems, however, depends on the skills of the soldiers who operate them. For armor crewmen, survival may depend on how quickly and accurately they engage enemy targets. Speed and accuracy in tank gunnery are not easily learned and usually require many hours of hands-on practice. Because of the high cost of ammunition, the number of rounds allocated for training has been reduced in recent years. The required proficiency levels can no longer be achieved by training that relies heavily on the expenditure of live ammunition (US Army Armor School, 1981). Tank gunnery training devices have therefore been developed that permit extended firing practice while saving costly ammunition (Department of the Army, 1984; US Army Armor Center, 1984). The present research investigates the training effectiveness of two of these devices, the MK1 Videodisk Gunnery Simulator (VIGS) and the M1 Unit Conduct of Fire Trainer (UCOFT). Each of these devices is designed to train and sustain M1 tank gunnery skills.

The M1 VIGS is a part-task, table-top trainer that uses videodisk media to present filmed target scenes to the gunner. It is a medium fidelity device equipped with a single sight, the gunner's primary sight, and most of the switches and controls that the gunner uses in live-fire gunnery engagements on the tank. The basic components of the M1 VIGS are shown in Figure 1. The M1 VIGS includes a gunner's console, a videodisk player for generating the target scenes, and a floppy disk drive to provide software control for the system. A prototype research version of the M1 VIGS also includes a separate operator's station consisting of an operator's terminal for initiating engagements and other events, a performance monitor for observing the gunner's performance in real time, and a printer for producing a hard copy of the gunner's performance. These optional components, found only in the research version, are shown in Figure 2.

The M1 UCOFT is a high fidelity gunnery trainer that allows the gunner and tank commander to practice almost all of the required tasks. The major UCOFT subsystems (Figure 3) include an instructor/operator's station, an enclosed crew station, a special purpose computer and a general purpose computer (Instructor's Utilization Handbook, 1985). The instructor/operator's station includes separate monitors for the gunner's and tank commander's sights, an instructor's control terminal, and a printer for recording the crew's performance. The crew station contains the Gunner's Primary Sight (GPS), the Gunner's Auxiliary Sight (GAS), the Gunner's Primary Sight Extension (GPSE) for the tank commander, the tank commander's Forward Unity Periscope (FUP), and nearly all of the switches and controls used by the gunner and tank commander in the M1 tank. Figures 4 and 5 show the gunner's and tank commander's stations that constitute the UCOFT crew station. The

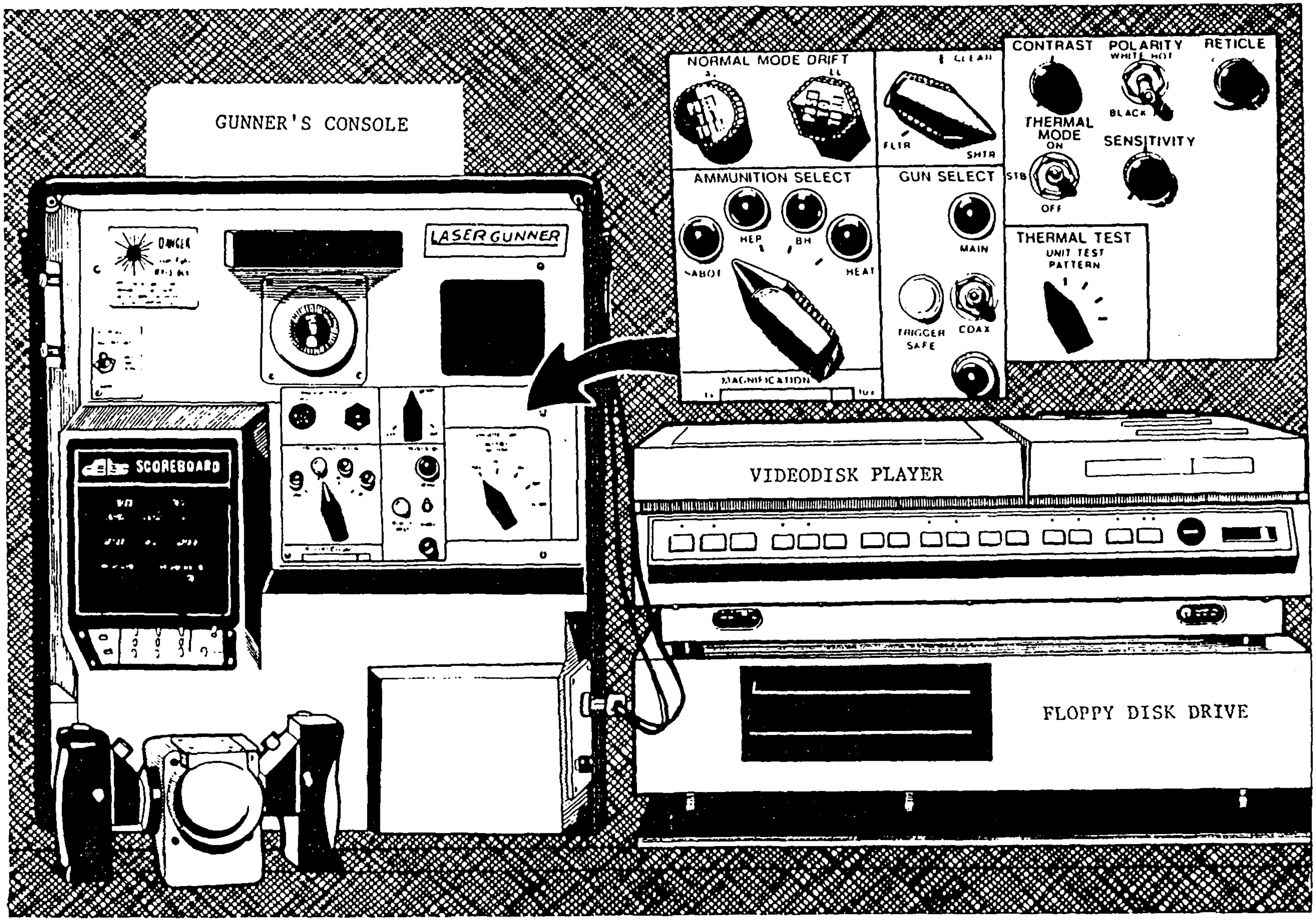


Figure 1. M1 Videodisk Gunnery Simulator Basic Components

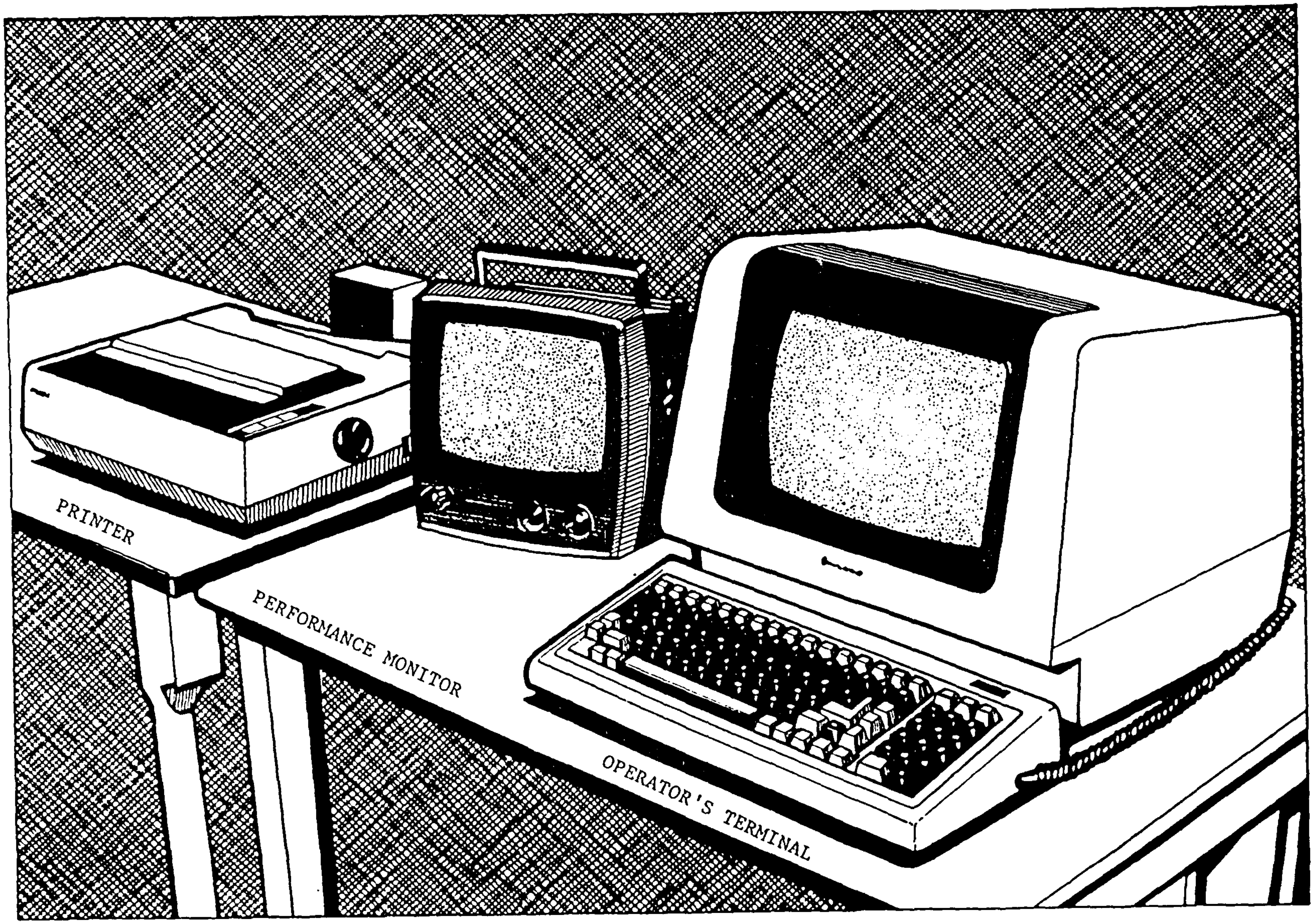


Figure 2. M1 Videodisk Gunnery Simulator Optional Components

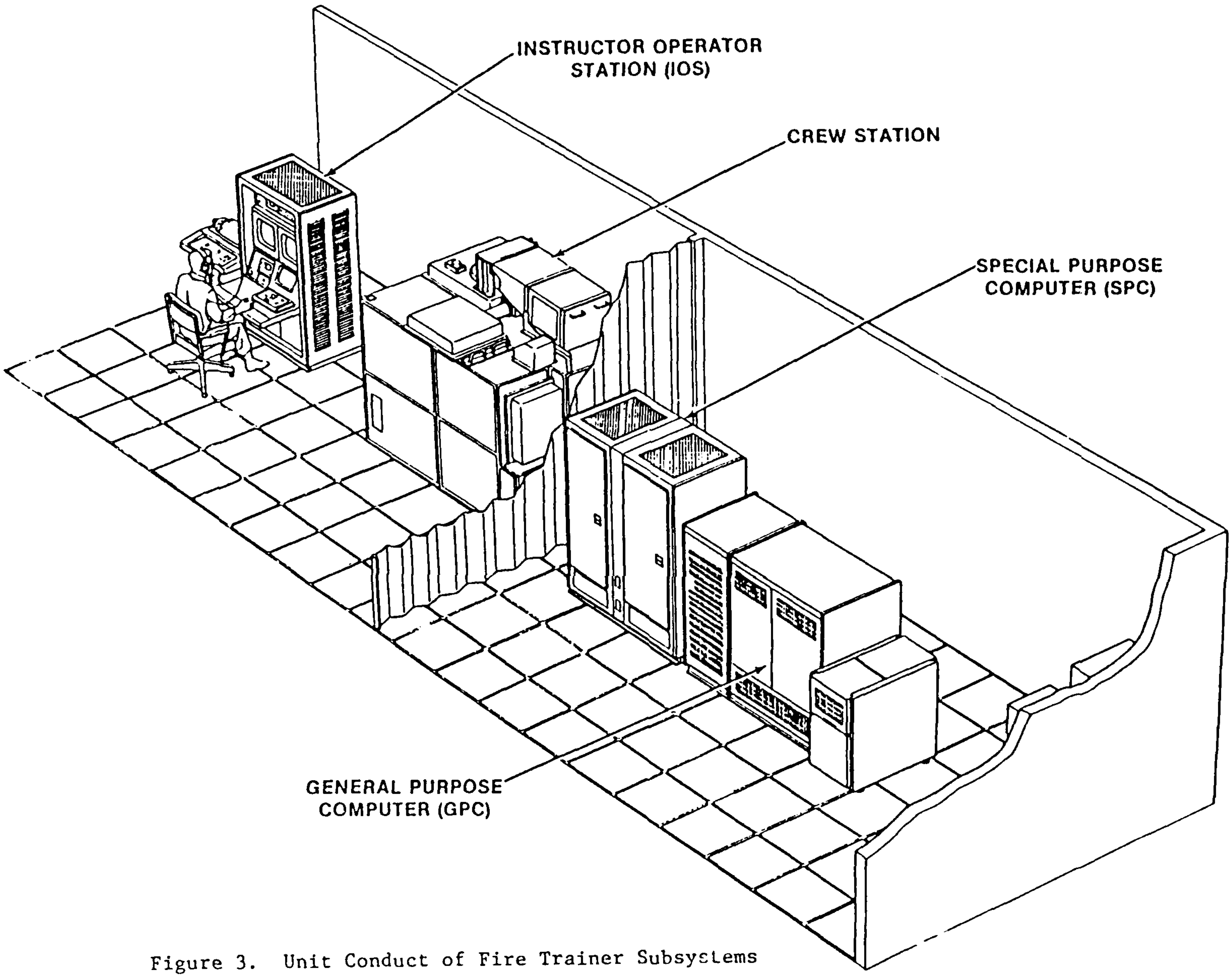
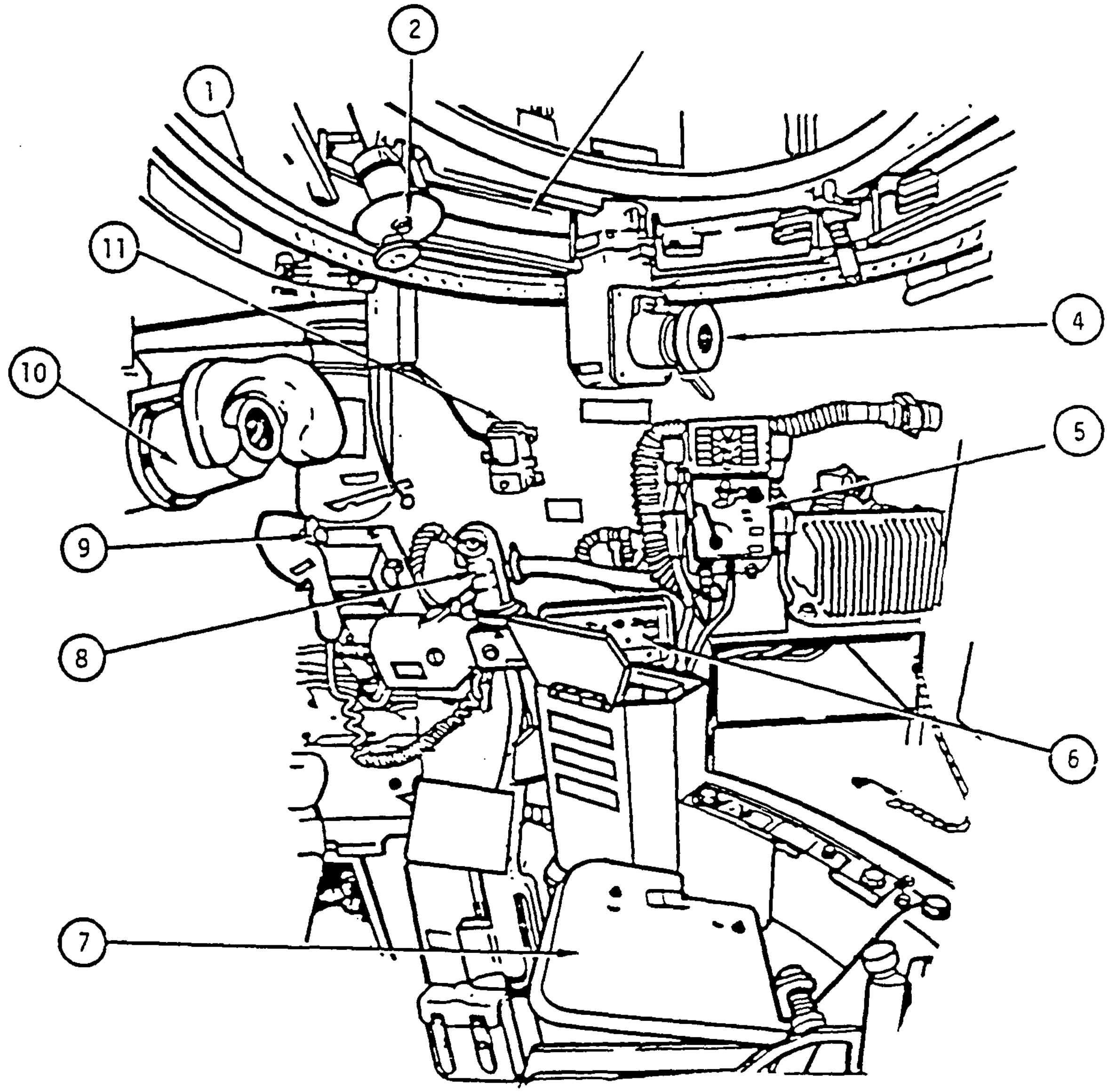
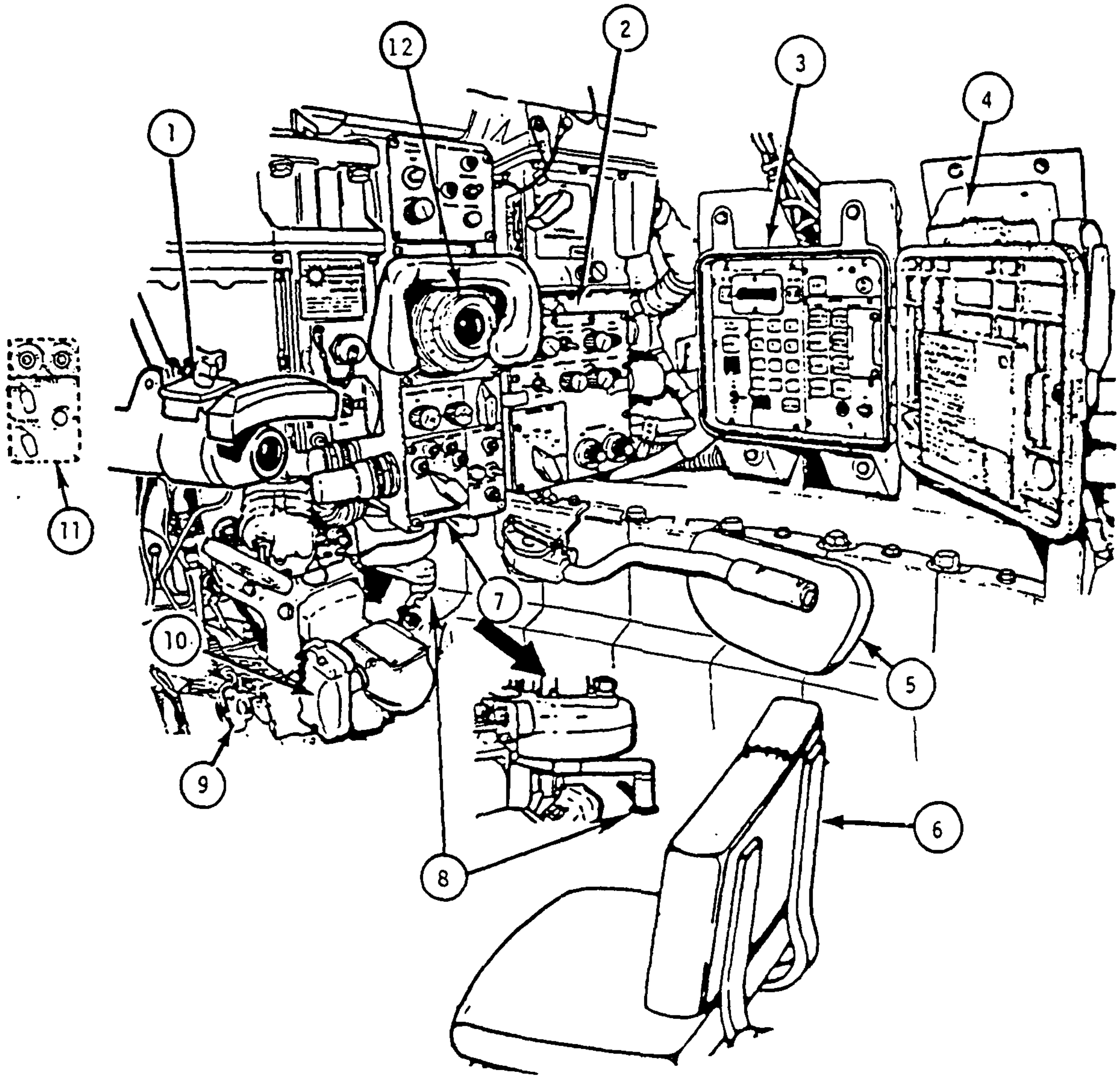


Figure 3. Unit Conduct of Fire Trainer Subsystems



1	CWS MANUAL TRAVERSE RING	7	SEAT
2	MANUAL ELEVATION CONTROL	8	COMMANDER CONTROL HANDLE
3	FUP	9	CWS CONTROL HANDLE
4	CWSS	10	GPSE
5	INTERCOM CONTROL SET	11	DOME LIGHT
6	COMMANDER'S CONTROL PANEL		

Figure 4. Unit Conduct of Fire Trainer Tank Commander's Station



1 GAS
2 TIS CONTROL PANEL
3 BALLISTIC COMPUTER CONTROL PANEL
4 INTERCOM CONTROL SET
5 CHEST REST
6 SEAT
7 GPS CONTROL PANEL
8 MANUAL TRAVERSE HANDLE
9 MANUAL ELEVATION HANDLE
10 GUNNER'S CONTROL HANDLE
11 GAS CONTROL PANEL
12 GPS

Figure 5. Unit Conduct of Fire Trainer Tank Gunner's Station

special purpose computer produces the computer-generated scenes presented through the gunner's and tank commander's sights. The general purpose computer provides control for the other UCOFT subsystems and manages the UCOFT training and evaluation systems.

The VIGS and the UCOFT are similar in that they both permit the gunner to acquire, track, and fire at moving and stationary targets. They differ in the number and kinds of engagements available and the sights and weapons simulated for firing those engagements. The UCOFT simulates more weapons and sights and has a much larger library of target engagements. The UCOFT includes a large number of multiple target and degraded gunnery engagements that are not available for the VIGS. The UCOFT also permits training the gunner and tank commander as a team whereas the VIGS does not. While the UCOFT has many more capabilities than the VIGS, it also costs about forty times as much. The VIGS used in this research sells for about $40,000, while the UCOFT costs about $1,900,000.

Evaluating Gunnery Training Devices

Though the Army is proceeding with its plans to field the UCOFT and will likely field some form of the VIGS, the manner in which these devices might be integrated into a gunnery training program has not been fully determined. One suggested approach is to use the VIGS for building and sustaining basic gunnery skills and the UCOFT for improving and broadening those skills (Brown, 1983; US Army Armor Center, 1984). Evidence showing that gunnery skills learned on the VIGS enhance performance on the UCOFT, or that skills learned on either device translate to increased proficiency on the tank is lacking. Several studies (Deason, Robinson, and Terrell, 1978; Kuma and McConville, 1982; Hoffman & Melching, 1983; Martellaro, Thorne, Bryant, and Pierce, 1985) have examined transfer between VIGS or UCOFT and live fire gunnery performance. However, these studies do not provide convincing evidence that transfer occurs because of flaws in their design. As Boldovici and Sabat (1985) state, "Many evaluations of Army training devices have contained at least one design flaw of such severity as to preclude establishing a relation between device-mediated practice on one hand, and weapon system proficiency on the other" (p.3). Boldovici and Sabat list several sources of error that plague transfer studies. The most common sources of error in recent evaluations of training devices are: (1) Small numbers of subjects are used in the evaluation; (2) Subjects are not assigned randomly to groups; (3) Groups are treated differently in respects other than those under investigation; and (4) The criteria (i.e., live-fire gunnery tests) used to evaluate these devices are frequently not reliable.

The first three sources of error may be eliminated by better research designs and more careful execution of those designs. Test reliability, however, remains a problem because of the unreliability of live-fire gunnery tests. Unreliability of live-fire tests is the result of several factors. One factor that reduces the reliability of live-fire tests is weapon system error; that is, rounds miss the target despite correct performance by the tank crew. For example, Fingerman (1978) found that with perfect sight pictures M60A1 tank crews missed targets two times for each ten rounds fired. These misses were attributed to inaccuracies in the M60 fire control system and dispersion of main gun rounds. While this figure may be smaller for newer

systems such as the M1 tank, round-to-round dispersion and other factors still result in missed targets despite perfect sight pictures. Another factor that tends to decrease reliability is the difficulty of scoring live-fire exercises. Eaton and Whalen (1980) used videotape to count hits and misses on a day live-fire exercise. Using the videotape-derived scores as the standard, they found that traditional scoring methods (e.g., binoculars, periscope) produced hit/miss data that were discrepant with the videotape scores. Eaton and Whalen, however, did not report interscorer reliability for the videotape scoring, which, according to J.A. Boldovici (personal communication, November 13, 1986) may be as low as .80 with untrained scorers. Boldovici suggests that higher reliabilities may have been obtained had trained scorers and better video equipment with slow motion and freeze frame features been used. Quality video equipment may be expensive, however, and may not be readily available to evaluators. The cost of video equipment and its unavailability, as well as the additional time required to score the videotapes, may explain why videotape scoring methods are not routinely used. Even when videotape is used, the high cost of main gun rounds tends to limit the number of rounds fired by each crew. This creates a situation in which the sample of gunnery behavior is too small to adequately test the gunnery skills in question. Reliability of live-fire tests may be increased by permitting crews to fire more rounds, but the high cost of rounds prohibits this solution.

One suggestion to improve the reliability of live-fire tests is to use through-the-sight video to record the accuracy with which the gunner places the reticle on target. This technique of measuring a gunner's accuracy eliminates fire control system inaccuracies, round-to-round dispersion, and problems in scoring the strike of a round as sources of measurement error. In theory, through-the-sight video should provide the solution to the live-fire reliability problem. In practice, through-the-sight video is difficult to implement in live-fire gunnery tests and technical problems are often encountered (Hoffman, Melching, 1983). Even if this technique were perfected for routine measurement applications, the availability of main gun rounds tends to limit the length of the live-fire tests, and reduce their reliability. Furthermore, scoring the videotaped engagements remains a tedious and time consuming task.

The reliability problem associated with live-fire tests suggest that alternatives are needed for evaluating tank gunnery training devices. Boldovici and Sabat (1985) suggest using dry-fire and sight-picture photography, perhaps combined with verbal measures of critical knowledges, as substitutes for live-fire tests. Boldovici, Kraemer, Lampton (1986) have used still sight picture photography in dry-fire tests with encouraging results. This technique involves taking a photograph through the sight of the gunner's reticle aim at the time of simulated firing. Interscorer reliabilities averaging .95 were obtained using the technique for determining hits and misses. Fire times and procedural errors were measured and recorded manually for the dry fire test. Boldovici et al. (1986) have not reported reliability data for the time and error measures, but these manually recorded measures might be expected to be less reliable than those automatically recorded by computer-based simulators. On the other hand, the validity of dry-fire tests may be higher than device-mediated tests because gunners use the same equipment during dry-fire tests as they use in the field.

Another approach to evaluating training devices is to use performance on one device as the criterion for determining the effectiveness of training on a second device. This approach requires measuring training transfer between devices, and is appropriate to situations where the devices are to be used in the same training program. Three outcomes, with different training implications, are possible when this approach is used: (1) positive transfer of skills, (2) no skill transfer, and (3) negative transfer. Demonstrating positive transfer between two training devices would suggest that the devices are tapping common skills, perhaps the same skills that are required for proficient performance on the weapon system. Such an outcome would indicate that the devices may be used effectively together in the same training program. If skills learned on one device do not transfer to the other device, then either the devices are each training different sets of skills needed on the weapon system, or training provided on one or both of the devices is not teaching the required skills. Unless it can be shown that the devices are training different gunnery skills, a finding of no transfer suggests that the devices should not be used together in training. Demonstrating negative transfer between devices would suggest that skills learned on one device interfere with performance on the other device and may interfere with performance on the weapon system. An outcome of negative transfer implies that the devices should not be used together, and that modification of one of the devices may be necessary.

Demonstrating transfer of training between devices requires reliable performance measures. Devices improve the reliability of measurements through such features as automated scoring and recording of performance and the capability to present the same scenarios under constant conditions to each soldier tested. Unlike live-fire testing, gunners tested on devices can fire as many rounds as time permits--another feature that tends to improve reliability. Graham (1986) has shown that gunnery performance can be reliably measured on the UCOFT using a test consisting of 32 engagements. Graham obtained test-retest reliabilities ranging from .72 to .87 on six of nine gunnery performance measures. These results demonstrate that gunnery performances can be reliably measured on automated gunnery training devices such as the UCOFT.

Reliable performance tests are required to evaluate training transfer for training devices, but other factors must also be considered in designing experiments to evaluate transfer. According to the principle of inclusion, the second task must include all essential elements of the first task (Holding, 1965). In training gunnery, it may be important to include the same type of engagements (i.e., target range, target movement, visibility) in the test as are presented during training. It would not be appropriate, for example, to train long-range moving targets on a simulator and test gunners with a live-fire exercise that consists entirely of stationary short-range targets. If a particular sight is to be used or if multiple targets or degraded engagements are to be presented during testing, then training on the simulator should include similar conditions. Failure to consider testing conditions when designing the simulator training will reduce the chances of obtaining training transfer.

Training transfer is critically dependent on initial learning and retention of what was learned. As stated by Klausmeir and Goodwin (1966), "No learning outcome transfers to a new situation unless it is retained, and no

retention occurs unless something is initially learned." Thus it becomes important to demonstrate that initial learning has occurred before administering the test of training transfer. Initial learning may be demonstrated either by comparing pre-training and post-training scores or by measuring performance on a set of engagements over several repetitions. In either case, equivalent sets of engagements can be constructed for measuring learning on the simulator or performance improvement on a single set of simulator engagements can be measured. If a single set of engagements is used, however, precautions should be taken to insure that performance improvement is not confined to the particular engagements included in the set. Including a sufficiently large number of engagements in the set and varying the order in which they are presented from one repetition to the next will help prevent the learning from being engagement-specific. When equivalent sets of engagements are used, pilot tests should be conducted to verify that the equivalent sets comprise engagements of the same type and are equally difficult.

The skill level of the soldiers at the onset of simulator training will influence initial learning and hence training transfer. Experienced gunners with excellent gunnery skills at the onset may require many engagements on the simulator to show significant performance improvement, whereas inexperienced gunners may demonstrate rapid improvement with fewer engagements. The number of engagements trained on the simulator is an important factor and may lead to erroneous conclusions if it is ignored. A sufficient number of engagements must be included for significant learning to occur in the test population, yet not so many that little additional learning occurs or that content-specific habits are learned that interfere with transfer. When the simulator situation contains elements inappropriate for successful performance in the operational situation, continued simulator practice may lead to increased dominance of content-specific habits that interfere with operational performance (Weitz & Adler, 1973). For example, one prototype gunnery simulator rewarded gunners for firing on moving targets as soon as their reticle was on the target instead of requiring gunners to establish a smooth tracking rate before firing. Continued practice of this habit on the simulator could interfere with gunner performance on the tank because accuracy on the tank requires smooth tracking.

The difficulty level of engagements selected for determining transfer must provide a challenge to the soldiers involved and represent the domain of engagements that the simulator is designed to train. If the test consists of engagements that are too easy for the soldiers being tested, all soldiers may receive high scores on the test. Under these conditions transfer is seldom demonstrated, because the soldiers' initial high skill level typically results in uniformly high test performance for control and experimental groups alike. If engagements are selected that do not adequately train and test the full range of skills that the simulator is designed to train, the outcome will apply only to the subset of skills that are tested. This tends to reduce the generalizability of the results and restrict the conclusions regarding transfer, or the lack thereof, to the conditions under which the soldiers were tested.

Present Research Design Considerations

This research is designed to avoid many of the common pitfalls typically found in training transfer studies. The reliability problem is circumvented by using performance on one simulator as the criterion for transfer of training from another simulator. Test-retest reliability is measured to insure criterion reliability. Similar sets of engagements are used on each simulator, with target range and target motion controlled. Soldiers having little or no previous gunnery experience are used in order to increase the probability that learning will occur during a brief training session. A large set of short and long range engagements is administered on two successive occasions in order to evaluate learning on each training device. Finally, the difficulty level is sufficiently high that scoring the maximum on the test without previous training is unlikely.

Research Objectives and Hypotheses

The objectives of this research are to determine if skills learned on the VIGS transfer to the UCOFT and vice versa, and to determine if differences in transfer occur as a function of the order of device use in a training program. Similarities between the VIGS and UCOFT suggest that skills learned by novice gunners on one device should lead to better performance on the other device. That is, positive training transfer should occur from the VIGS to the UCOFT and from the UCOFT to the VIGS. The group trained on the UCOFT before performing on the VIGS is expected to exhibit VIGS performance that is superior to that of the group with no prior M1 simulator gunnery training. Similarly the group trained on the VIGS before performing on the UCOFT should perform better on the UCOFT than the group without prior training. Within-device learning on each device is expected, and should be demonstrated by significant performance increases from the first to the second replication of the VIGS or UCOFT exercises. As a minimum the following skills are expected to be learned on the VIGS or UCOFT and influence performance on the other device: (1) detecting targets in the thermal mode; (2) laying the primary sight reticle on targets; (3) tracking moving targets; (4) using the laser rangefinder to obtain target range, (5) selecting the correct ammunition in response to fire commands; and (6) firing on targets in response to fire commands. Improvements in speed and accuracy of engaging targets should occur as a function of learning these skills.

METHOD

Subjects

The subjects were 24 soldiers assigned to M60A3 armor units at Fort Knox. They had served an average of 17 months in armor and had no experience on the M1 tank. All of the soldiers had received a small amount of gunnery training before being assigned to their unit. In addition 6 of the 24 soldiers reported serving as gunners on M60A3 tanks in their unit. These six gunners averaged five months of gunnery experience. Most of the remaining subjects were tank drivers and loaders, with one jeep driver and one clerk typist. Biographical data for the subjects are summarized in Appendix A.

Equipment and Materials

The primary equipment consisted of M1 Unit Conduct of Fire Trainers (UCOFTs) manufactured by the General Electric Company and a prototype M1 VIGS designed by Perceptronics, Incorporated. Both trainers included external monitors for real-time monitoring of gunnery performance by the instructors and the experimenter, and printers for permanently recording performance data. Tape recorders were used for administering instructions and data forms were employed to manually record procedural errors and target identification times for the VIGS. Biographical information was obtained from questionnaires administered to the subjects. A copy of the biographical questionnaire is included as Appendix B.

Procedure

Subjects were randomly assigned to two groups of 12 subjects each. One group of subjects, the VIGS-first group, was initially trained as gunners on the VIGS followed by testing on the UCOFT. The other group, the UCOFT-first group, was trained first on the UCOFT and then tested on the VIGS. Each group received the same number of trials (i.e., gunnery engagements) on both devices. The only difference between the groups was the order in which they received training on the two devices. VIGS training consisted of engaging 27 single moving targets in two successive replications. UCOFT training was conducted in the same manner. Therefore subjects performed 27 x 2 = 54 engagements on the VIGS and 54 similar engagements on the UCOFT. Table 1 shows the order of training and testing for the two groups of subjects. Note that the engagements used for testing the UCOFT-first group were identical to those for training the VIGS-first group. Similarly, engagements used to test the VIGS-first group were the same engagements used in training the UCOFT-first group.

Table 1

Sequence of Training and Testing for VIGS-first and UCOFT-first Groups

Group	Phase I - Training	Phase II - Testing
VIGS-first	VIGS training (54 engagements)	UCOFT test (54 engagements)
UCOFT-first	UCOFT training (54 engagements)	VIGS test (54 engagements)

Engagements presented on the UCOFT were similar but not identical to those presented on the VIGS. The number of short-range and long-range targets presented on the VIGS were equal to the number presented on the UCOFT. All targets were moving, but target speed and movement direction were not controlled and varied from one engagement to the next, and perhaps from one

device to the next. Target exposure times differed for the devices, with VIGS targets being exposed from 35 to 40 seconds, or about twice that of UCOFT targets. Both VIGS and UCOFT targets were engaged in the thermal mode from a simulated stationary tank. The thermal mode was used because of the unavailability of daylight target scenes for the prototype VIGS.

Before training on either device, subjects were given instructions explaining the experimental procedures (See Appendix C) and were familiarized with the switches/controls and operating procedures for each device. Subjects were also shown examples of each type of target (e.g., tank, chopper, APC) by the instructor/operator. Following the familiarization, subjects were allowed to engage four targets under the direction of the UCOFT or VIGS instructor/operator. These four warm-up trials familiarized the subjects with visual target presentation and provided them pre-training practice in operating the gunner's control handles and switches. The entire familiarization, including the warm-up trials took about 30 minutes to complete.

Three UCOFT instructor/operators and a VIGS instructor/operator administered the gunnery training to the soldiers. Each instructor/operator administered the pre-specified gunnery engagements in the prescribed order. Instructor-provided assistance and feedback were minimal. The instructor/operators assisted soldiers in locating targets and informed them when they made procedural system management errors. The instructor/operators also answered questions raised by the soldiers during the training. No other instructor-provided assistance or feedback was given. Feedback on the accuracy of each round was provided by an explosion graphic superimposed on the target by the VIGS and UCOFT systems.

The UCOFT is designed for training gunners and tank commanders in pairs. Thus tank commanders (TCs) were selected and trained to perform TC functions such as giving fire commands and laying the gun tube in the general direction of the target. Three TCs, confederates of the experimenter, were used in this research. All three had previous TC experience - one on the UCOFT, one on the M1 tank, and the third had experience on both tank and UCOFT. Gunners were assigned randomly to the TCs, conditional upon each TC being paired with equal numbers of gunners from each of the two groups.

Differences in device capabilities and the presence of the TC in the UCOFT produced some differences between the target engagement procedures performed by the gunners for the VIGS and UCOFT. A trial on the VIGS began with the target in the gunner's field of view, but on the UCOFT the target initially appeared in the TC's forward unity periscope. In the UCOFT, the TC located the target, laid the gun for direction, told the driver to move out and issued the fire command. For the VIGS, a prerecorded fire command was issued automatically shortly after the target was presented. The fire command identified the target and type of ammunition to be fired. The gunner announced "Identified" when he spotted the target and moved the reticle onto the target using the gunner control handles. For the UCOFT, the gunner switched his sight from three to ten power before laying the reticle on target. Placing the reticle on target, the gunner tracked the target as it moved, and fired on the target. If the first round missed, the gunner reengaged the target, time permitting. Additional UCOFT rounds were provided in case of a second round miss, but gunners seldom fired more than two rounds

because of time constraints. To keep the number of rounds fired approximately equal for the two devices, only two rounds per engagement were allotted on the VIGS. The VIGS engagement ended when the target was hit, when the second round was fired, or after 35 to 40 seconds. On the UCOFT, the engagement ended either when the target was hit or when the gunner's tank was exposed more than 18 seconds, and killed by a simulated enemy round.

Performance Measures

Measures of speed and accuracy were recorded for each engagement. Measures included opening time (time from target presentation until firing the first round), identification time (time from target presentation until the gunner announces "Identified"), hit time (time to achieve a target hit), hit/miss, and aiming error (miss distance in azimuth and elevation from target center of mass). Because of software differences in the devices, aiming errors were recorded for hits and misses on the UCOFT, but only for misses on the VIGS. Hit/miss data were used to derive two additional measures of accuracy, first-round hit percentage and total hit percentage. The first of these was obtained by dividing the total number of first-round hits by the number of engagements presented. The second was calculated by dividing the total number of hits by the number of engagements.

In addition to speed and accuracy measures, procedural system management errors were measured for each device. On the VIGS, an error was manually recorded when the wrong ammunition was indexed or when the gunner failed to activate the laser rangefinder to obtain target range before firing. On the UCOFT, a system management error was automatically recorded for indexing the wrong ammunition, failing to activate the laser rangefinder prior to firing, firing with the GPS in low power, or exposing own tank for more than 15 seconds before returning to a defilade position.

Design and Analyses

Four measures of firing accuracy (percent first-round hits, percent hits, azimuth aiming error, elevation aiming error), three measures of engagement speed (identification time, opening time, hit time) and the number of system management errors were entered into a MANOVA, with repeated measures on the within subject factors. The design is outlined in Table 2. Within subject factors are device (VIGS or UCOFT) and replication (first or second replication of a set of 27 gunnery engagements). One between-subjects factor, group membership, was included. One group received VIGS training and was tested on UCOFT, while the other group received UCOFT training and was tested on VIGS. The data were analyzed using the "doubly multivariate repeated measures" design from the Statistical Package for the Social Sciences (SPSS-X) system.

Table 2

Split Plot Factorial 2.22 Design

	VIGS		UCOFT	
	REP1	REP2	REP 1	REP2
n=12 GRP1				
n=12 GRP2				

The design presented in Table 2 permitted the examination of: (1) differences in training transfer as a function of order of device presentation (GRP effect), (2) performance improvement over replications (REP effect), (3) performance level as a function of the device on which performance is measured (DEV effect), (4) training transfer between devices (GRP x DEV effect), (5) differential learning for the two groups (GRP x REP effect) and (6) differential improvement on the two devices (DEV x REP effect). Additional analyses were performed to investigate within-device improvement and within-device improvement by group.

Correlational analyses were used to determine the reliability of the 54-item performance test employed with each device and to ascertain the extent to which performance on one device predicts performance on the other device. Biographical variables were correlated with performance measures to identify other predictors of gunnery performance. The correlations were performed using Pearson correlation procedures from the SPSS-X statistical package.

RESULTS & DISCUSSION

Test-Retest Reliability

Test-retest reliabilities for the VIGS and UCOFT 54-item tests were calculated for each performance measure. The reliabilities were obtained by correlating the soldiers' scores for the first replication with their scores for the second replication. The Spearman-Brown formula was used to correct for test length (Anastasi, 1968). The corrected reliabilities are presented in Table 3. A high reliability suggests that performance is relatively stable when Ss are retested on the same gunnery engagements. That is, gunners who perform well on the first replication maintain their ranking on the second replication relative to gunners who performed poorly on the first replication. On the VIGS, the more reliable measures were hit percentage, first round hit percentage, identification time, opening time and hit time. With the exception of hit time, these same measures were also reliable on the UCOFT. Note that aiming errors and system management errors were less stable

in general than other measures of gunnery proficiency. These results suggest that for measuring firing accuracy on the VIGS or UCOFT, first-round and overall hit percentages may be preferable to azimuth and elevation aiming errors. Similarly the lack of stability for system management errors may reduce the usefulness of this measure for evaluating gunner proficiency.

Table 3

Reliability Coefficient of VIGS and UCOFT Tests Corrected for Test Length

Performance Measures	VIGS Test-Retest Reliability Coefficients	UCOFT Test-Retest Reliability Coefficients
Hit Percentage	.81	.67
First Round Hit Percentage	.77	.72
Azimuth Aiming Error	.37	.37
Elevation Aiming Error	.67	.18
Identification Time	.79	.92
Opening Time	.92	.71
Hit Time	.91	.41
System Management Errors	.13	.18

One must be careful, however, in interpreting low test-retest reliabilities as an indictment against the usefulness of particular gunnery performance measures. In this research, significant learning was occurring from the first to the second replication. It is entirely possible that the most sensitive measures of learning may have lower reliabilities because of differential learning effects. For example, gunners who initially exhibited small aiming errors may have improved little from the first to the second replication, whereas gunners who performed poorly initially may have improved dramatically. Differential improvement in performance between good and poor performers would tend to reduce variances from the first to the second replication. Examination of the variances for the performance measures supports the notion that differential learning is producing large decreases in variance from the first to second replication, and the largest decreases are for those measures showing low reliabilities. To further examine the hypothesis that differential learning contributed to the low reliabilities, gunners were divided into high and low performing groups on the basis of their scores on the first replication. Difference scores showing improvement from the first to second replication were calculated for individuals within each group and the group means of these differences were compared using *t*-tests. Significant *t*'s were obtained for hit time, azimuth aiming error and elevation aiming error on the UCOFT but not for first round hit percentage. On the VIGS, significant *t*'s were obtained for azimuth and elevation aiming error but not for hit time or first round hit percentage. These results also support the hypothesis that the low reliabilities observed for some performance measures are associated with differential learning effects. Table D-1, D-2, and D-3

in Appendix D show variability data and *t*-test results supporting the existence of differential learning effects. Given the number of significant *t*'s and the pattern of results obtained, the likelihood of producing these results by chance is highly unlikely despite the multiple *t*-tests performed.

In examining Table 3, note that reliabilities for measures of elevation aiming error and hit time are substantially lower for the UCOFT than for the VIGS. For the elevation aiming error measure, the reliability difference may be attributed to the initial difficulty that some gunners experience in laying the reticle precisely in elevation on the UCOFT. This initial difficulty results in large differences between the performances of individuals on the first replication, with the differences decreasing on the second replication. Because soldiers do not maintain their performance levels from the first to the second replication relative to their cohorts, reliability decreases. Thus differential learning of laying the reticle in elevation on the UCOFT, but not on the VIGS, may account for the different reliabilities for the two devices. This explanation is supported by the data in Tables D-1 and D-2, which show greater decreases in the variability of the elevation aiming error for the UCOFT than for the VIGS. The data in these tables also show large decreases in variability in hit time from one replication to the next for UCOFT, but not for the VIGS. Soldiers who were slow in engaging UCOFT targets on the first replication improved considerably on the second replication, so that their performance levels approached those of the soldiers that were relatively fast initially. Reliability differences in UCOFT and VIGS measures are therefore probably due to the differential learning effects on the UCOFT.

Performance Prediction

Predictors of job performance are highly valued because of their potential to increase organizational effectiveness and efficiency. Attempts to predict tank gunnery performance have met with little success. Neither paper-and-pencil ability measures nor job-sample tests have been particularly successful in predicting gunnery performance (Eaton, Johnson, & Black, 1980). Simulator-based measures of gunnery performance taken on the VIGS or UCOFT might be expected to accurately predict tank gunnery proficiency. Because both VIGS and UCOFT were designed to train tank gunnery performance, performances measured on one device should predict performances on the other device. Accurate predictors are indicated by high correlations between like measures of performance on the two devices.

Table 4 shows correlations between various measures of gunnery performance on the VIGS and UCOFT. Significant correlations were obtained for three of the four accuracy measures, but for none of the speed measures. This suggests that accuracy, but not speed measures may be predicted from one simulator to the other. Gunners who shoot accurately on the VIGS also shoot accurately on the UCOFT. No relationship between speed of target engagements on the two devices was found, however. The lack of relationship between speed on the two devices may be due in part to the TC's contribution to engagement times on the UCOFT. The requirement to interact with a live TC on the UCOFT tended to produce slower engagement times on the UCOFT than were observed on the VIGS. This overall slowing of engagement times may have reduced speed differences between subjects producing low correlations between

speed measures on the two devices. A moderate, but nonsignificant, correlation was obtained between the number of system management errors made on the two devices. This correlation was probably reduced somewhat because the UCOFT recorded two additional types of system management errors not recorded on the VIGS.

Table 4

Performance Measures Taken on One Device as Predictors of Performance on the other Device

Performance Measure	Pearson *r*	Significance Level
Hit Percentage	.50	.05
First Rnd Hit Percentage	.58	.01
Azimuth Aiming Error	.20	N.S.
Elevation Aiming Error	.52	.01
Identification Time	-.02	NS
Opening Time	-.08	NS
Hit Time	.14	NS
System Management Errors	.39	NS

The relationship between gunnery performance measures and biographical variables was evaluated using correlation procedures. In contrast to the performance predictors described above, none of the biographical measures correlate significantly with either VIGS or UCOFT performance measures. The results are included as Table E-1 in Appendix E. These results suggest that general measures of ability and experience such as education level, general technical score and armor experience may not predict the gunnery performance of novice gunners. Clearly the ability and experience measures did not predict proficiency for the novice gunners on the long and short range moving target engagements used in this research. Because the gunnery experience of most of the soldiers participating in this research was a month or less the relationship between amount of previous gunnery experience and performance on each device could not be evaluated.

MANOVA Results

A multivariate analysis of variance with repeated measures was performed using hit percentage, first round hit percentage, azimuth aiming error, elevation aiming error, identification time, opening time, hit time and system

management errors as the dependent measures. The results of the analysis are presented in Table 5. Significant main effects for replication (REP) and device (DEV) were obtained, but the group effect (GRP) was not significant. A significant device by replication interaction was found. The results are discussed fully in subsequent sections of this report.

Table 5

MANOVA Results

Effect	Wilks Lambda	Approximate Multiple F	DF	Significance of F
GRP	0.5018	1.86	8,15	0.143
DEV	0.0246	74.24	8,15	0.000
REP	0.0916	18.59	8,15	0.000
GRPxDEV	0.6295	1.10	8,15	0.413
GRPxREP	0.7158	0.74	8,15	0.653
DEVxREP	0.1240	13.25	8,15	0.000
GRPxREPxDEV	0.5774	1.37	8,15	0.284

Crosstraining and Gunnery Performance

The soldiers who served as subjects in this experiment had no gunnery experience on the M1 tank, and most were serving as M60A3 drivers or loaders. The gunnery training that they received on the M1 gunnery simulators must therefore be considered crosstraining. Significant improvement in performance on these simulators suggests that the M60A3 crewmen are learning M1 gunnery skills. As mentioned earlier training transfer depends on prior learning. If learning cannot be demonstrated, then one should not be surprised by an outcome that suggests no transfer. In this evaluation, evidence of learning is provided by improvement in gunnery performance from the first to the second replication of the 27 thermal gunnery engagements. The data in Table 6 suggest that gunnery improvement occurs on both devices; increases in hit percentages and decreases in engagement speed and number of errors were obtained. A significant main effect for replication in the MANOVA supports the hypothesis that gunnery performance improves over replications. Additional analyses reveal significant performance improvements with both VIGS ($F_{8,15} = 6.84$, $p<.001$) and UCOFT ($F_{8,15} = 12.42$, $p<.0005$) when VIGS and UCOFT performances are considered separately. When the VIGS performance of the VIGS-first group and the UCOFT performance of the UCOFT-first group are evaluated in separate MANOVAS, however, the improvement in performance fails to reach the chosen significance level for the VIGS ($F_{8,4} = 4.40$, $p>.08$) or the

UCOFT ($F_{8,4}$ = 4.30, p>.08). These results are likely the result of the small number of degrees of freedom (df) in the error term. Decreasing the number of dependent measures from eight to four increases the error term df, and yields significant within group performance improvements for both VIGS ($F_{4,8}$ = 11.24, p<.002) and UCOFT ($F_{4,8}$ = 8.13, p<.006).

Table 6

Means and Standard Deviations of Gunnery Performance on VIGS and UCOFT for Two Replications of Gunnery Test

	VIGS Performance				UCOFT Performance			
	REP1		REP2		REP1		REP2	
Performance Measure	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hit Percentage	75.49	9.11	81.93	9.50	33.65	14.02	52.34	12.61
First Rnd Percentage	63.21	11.65	70.18	12.31	29.44	12.66	45.06	11.32
Azimuth Error	1.41	0.87	0.77	0.38	2.81	1.37	1.74	0.50
Elevation Error	0.51	0.24	0.36	0.21	0.79	0.45	0.58	0.29
Identification Time	2.91	1.11	2.23	0.90	5.95	2.60	4.33	1.90
Opening Time	9.71	2.18	8.10	2.14	17.50	2.08	15.40	1.78
Hit Time	10.57	1.91	9.32	2.07	19.64	2.82	17.59	2.09
Sys Mgmt Error	0.53	0.37	0.29	0.63	5.85	1.55	2.72	0.65

Though improvements in performance are clearly shown for both devices, examination of Table 6 suggests that UCOFT performance improves more than VIGS performance. For example the mean improvement in hit percentage is six percentage points for VIGS but 21 points for the UCOFT. Similarly, average hit times improve by 1.25 seconds on VIGS but 2.05 seconds on UCOFT. The significant device by replication interaction from the MANOVA supports the conclusion that greater improvement occurs in UCOFT performance than in VIGS performance. These data suggest that learning progresses differently for the two devices. VIGS performance starts at a relatively high level and improves gradually, whereas UCOFT performance starts at a much lower level and increases more rapidly. The reason for differences in initial performance levels and learning rates on the two devices arise from requirements placed on the gunners by each device. As configured in this experiment the UCOFT requires laying the gun faster and more accurately than the VIGS in order to achieve a target kill. With the UCOFT, the reticle must be aimed within the critical portion of the target silhouette that is sensitive to hit damage to achieve a target kill, but with the VIGS the only requirement to achieve a

hit is to lay the reticle on the target (with kill zone set for 100% of the target surface). The UCOFT engagement ends if the tank is exposed for more than 18 seconds, whereas the VIGS gunner may have as much as 35 to 40 seconds to engage a target. The UCOFT gunner also must perform additional procedures such as changing sight power from 3x to 10x and interacting with a live tank commander. These factors combine to increase the difficulty of UCOFT engagements relative to VIGS engagements, and this probably accounts for most of the differences in initial performance levels and learning rates on the two devices. Some differences, however, could be accounted for by differences in the instructional style of the instructor/operators because the VIGS and UCOFT instructor/operators were not one in the same.

Training Transfer

Prior learning and retention of that learning are necessary but not sufficient conditions for training transfer. For transfer to occur the prior learning must affect performance in the new situation. In this research prior learning on Device 1 must affect performance on Device 2; otherwise training transfer has not been demonstrated. Table 7 presents means and standard deviations for performance measures on each device. Inspection of the table suggests that the subject group who had prior training on the VIGS (VIGS-first group) performed better on the UCOFT than the group who had no prior training. However, the VIGS-first group also generally performed better on the VIGS than the group receiving prior UCOFT training. At first glance these results imply positive transfer from the VIGS to UCOFT, but negative transfer from the UCOFT to VIGS. Closer examination of Table 7 reveals that differences in the performance means for the two groups are small relative to the standard deviations. A MANOVA was performed to examine the statistical significance of these differences to address the transfer question.

Two effects from the MANOVA are relevant to the transfer question. A significant GROUP effect would provide evidence for transfer by showing that order affects transfer, thereby supporting the choice of a particular order in administering VIGS and UCOFT training. The results in Table 5 indicate, however, that the GROUP effect is not significant ($F_{8,15}=1.86$, $p>.14$). Thus the order in which VIGS and UCOFT are used in gunnery training does not appear to influence transfer. A significant GROUP X DEVICE interaction would also suggest that training transfer has occurred. Table 5 results show, however, that the GROUP X DEVICE interaction is not significant ($F_{8,15}=1.10$, $p>.41$). Thus no evidence exists to indicate that skills learned on one device transfer to the other device. Based on these results, trainers should not expect a brief period of practice on one device to influence later performance on the other device. The results provide no support for using a VIGS, UCOFT device mix in gunnery training. The lack of support for using the VIGS, UCOFT mix, however, should not be taken to mean that either device is ineffective in training gunnery skills.

Table 7

Means and Standard Deviations of Gunnery Performance on VIGS and UCOFT by Group

	UCOFT Performance				VIGS Performance			
Group	VIGS-FIRST		UCOFT-FIRST		UCOFT-FIRST		VIGS-FIRST	
Performance Measure	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hit Percentage	44.56	11.22	41.43	12.15	77.93	9.04	79.49	8.32
First Rnd Percentage	37.42	11.33	37.08	10.34	65.10	8.52	68.29	12.85
Azimuth Error	2.21	0.79	2.34	0.80	1.01	0.48	1.13	0.55
Elevation Error	0.62	0.22	0.74	0.34	0.47	0.23	0.36	0.13
Opening Time	16.03	1.41	16.87	1.92	9.79	2.31	7.95	1.04
Hit Time	18.32	1.97	18.91	2.01	10.95	2.02	8.90	0.89
Sys Mgmt Error	4.14	1.04	4.43	0.69	0.40	0.27	0.29	0.19

The significant positive correlations, reported earlier, between VIGS and UCOFT performance cannot be taken as evidence of training transfer between the VIGS and UCOFT. Gagne (1954) noted that high positive correlations between two performances do not establish the causal link which is necessary for demonstrating transfer between prior learning and subsequent learning or performance in a different situation. The positive correlations between VIGS and UCOFT performances do suggest that the same skills, abilities, or other attributes are required for high levels of performance on the two devices. But a positive correlation between performances does not indicate that something was learned on Device 1, nor does it mean that skills learned on Device 1 are retained and affect Device 2 performance. Thus a positive correlation between performance on the two devices fails to meet the necessary and sufficient conditions for demonstrating training transfer.

The failure of gunnery skills to transfer between VIGS and UCOFT is surprising, given the similarity of the gunnery engagements presented and the responses required by the devices. While it is true that the UCOFT requires some responses not needed on the VIGS, many of the same kinds of responses are required, such as responding to fire commands, laying on targets and tracking their movement, indexing ammunition, and lasing and firing on short and long range moving targets. One potentially critical difference between the VIGS and UCOFT involves the gunner control handles. The gunner control handles on the two devices require the gunners to respond differently. The UCOFT handles require finer movements to make a precise lay on the target

than do the VIGS handles, and, according to some gunners, do not move the reticle as easily or as smoothly as the handles on the M1 tank. The VIGS control handles do not have a center detente, whereas the UCOFT handles do. The center detente allows the gunner to feel when the handles are centered, thereby providing additional proprioceptive feedback. Differences in the feel and responsiveness of the gunner control handles may have interfered with the transfer of training from one device to the other.

The research design controlled many of the sources of error that may occur in transfer of training studies. The 24 subjects were randomly assigned to two groups of 12 for evaluating transfer effects. With this sample size, the probability of detecting a significant difference when in fact a difference exists is 0.84. Both groups of subjects received the same amount and same kinds of training on each of the two training devices. The groups differed only in which device they practiced first and therefore the order in which they were trained on the two devices. One group performed first on the VIGS (Device 1) and then on the UCOFT (Device 2). The other group performed first on the UCOFT (Device 1) and then on the VIGS (Device 2). Because the performance on one device was the criterion for evaluating transfer from the other device, reliabililties of the gunnery measures were high. Learning and retention of the skills learned on Device 1 was insured by allowing the subjects to perform a relatively large number of trials on that device, by providing performance feedback, and by immediately following training on Device 1 with a test on Device 2. Although the number of trials on Device 1 was clearly sufficient for learning to occur, the skills learned may have been specific to that device. The number of trials may not have been sufficient for subjects to acquire the general target acquisition and tracking skills that would lead to performance improvements on Device 2. Had additional training sessions been scheduled on Device 1 before testing for transfer to Device 2, the chances of demonstrating transfer may have been increased.

A significant GROUP effect would suggest that more transfer occurred for one group than for the other. Because the GROUP effect was not significant, one can safely conclude that transfer from VIGS to UCOFT did not differ from UCOFT to VIGS transfer. While it is possible, that equal amounts of transfer occurred for each group; the nonsignificant GROUP X DEVICE interaction suggested that this was not the case. However, the GROUP X DEVICE interaction may have been affected by non-specific sources of transfer (i.e., by warm-up, learning-to-learn, or fatigue). In evaluating the GROUP X DEVICE interaction, these non-specific sources of transfer are confounded with the specific skill transfer from one device to the other. Because warm-up and learning-to-learn effects tend to increase the net transfer from one device to the other, only fatigue could have altered the conclusion that brief periods of practice on VIGS or UCOFT fail to produce performance improvements on the other device.

Fatigue could have influenced the results by masking the effects of Device 1 practice on Device 2 performance. That is, subjects may have performed less well on Device 2 than predicted because of fatigue from their massed practice on Device 1. Fatigue is a plausible explanation because subjects engaged one target after another over a two to two and one-half hour period with only a ten-minute break for every 45 minutes of firing. But if fatigue is affecting performance to a significant degree, one might expect smaller increases from Replication 1 to Replication 2 in VIGS performance for

the UCOFT-first group, who should be fatigued from their UCOFT performance, than for the VIGS-first group whose first performance is on the VIGS. Similarly, if fatigue is affecting performance, the UCOFT performance of the VIGS-first group would be expected to improve less across replications than that of the UCOFT-first group. A nonsignificant GROUP by REPLICATION effect ($F_{8,15}$ = 0.74, p>.65) suggests that fatigue is not a major factor. Additional MANOVAS for analyzing performance on each device separately also fail to obtain a significant GROUP x REPLICATION interaction ($F_{5,18}$=.872, p>.75 for UCOFT and $F_{5,18}$=.869, p>.74 for VIGS). These results suggest that fatigue does not account for the lack of transfer between VIGS and UCOFT.

Another variable that could have influenced the outcome of this research is the instructor/operator. The UCOFT and VIGS exercises were administered by different instructor/operators. Although the research procedures dictated most of the actions of the instructor/operators, differences in the instructor style may have contributed to learning differences on the two devices. As mentioned earlier in this report, larger within-device performance improvements were obtained with the UCOFT than with the VIGS. These learning differences would be expected to produce more transfer from the device on which the superior learning was demonstrated (i.e., UCOFT) than from the other device. But the expected increase in training transfer was not obtained. This suggests that while the instructor variable may possibly have affected learning, it did not produce differences in the amount of training transfer because no transfer differences were observed.

SUMMARY

Two training devices for teaching M1 tank gunnery skills were used to investigate crosstraining and training transfer questions. The devices were a videodisk-based, part-task trainer, VIGS, and a high fidelity trainer, UCOFT, employing computer-generated imagery and realistic crew compartment. M60A3 soldiers were randomly assigned to two subject groups who received training on one device and then were tested on the other device. The VIGS-first group was trained on VIGS and tested on UCOFT, while the UCOFT-first group was trained on UCOFT and then tested on VIGS. A set of engagements was performed twice for each device in order to evaluate test reliability and within-device performance improvement. Correlational analyses were performed to identify gunnery performance predictors and a multivariate analysis of variance (MANOVA) was used to evaluate crosstraining and training transfer.

In general, the reliabilities of VIGS-based and UCOFT-based tests were high. Significant improvements in performance as a function of training were shown with each device, but the greatest improvements were seen with the UCOFT. Subjects who fired more accurately on the VIGS also fired more accurately on the UCOFT, suggesting that VIGS performance is a good predictor of UCOFT performance and vice versa. Measures of speed on the two devices, however, were not significantly correlated. None of the general ability or experience measures (e.g., general technical score, armor experience) predict gunnery performance. Despite high reliability, demonstrated performance improvement on each device, and the ability to predict accuracy scores on one device from scores on the other, no transfer of training between devices was demonstrated. This lack of transfer may be accounted for by insufficient practice on Device 1 during training or critical differences in the responses

required by the two training devices. Among the critical features of the devices that may have adversely affected training transfer are the gunner control handles. The control handles on the VIGS do not respond like those on the UCOFT, and control handles on both devices feel and respond differently from those on the M1 tank. Low-fidelity gunner control handles, a potentially critical simulation component for training gunnery skills, may reduce the effectiveness of gunnery simulation devices. Additional research is needed to determine whether transfer will occur with extended practice on Device 1, or if differences in simulator features, such as in the gunner control handles, are reducing training transfer. Unless other research shows that skills learned on the VIGS transfer to the UCOFT, or vice versa, or until changes are made in the design of those devices, a gunnery program that combines VIGS and UCOFT training cannot be recommended. This research provides no evidence to suggest that such a training program would be effective. However, the results of this research should not be interpreted to mean that the UCOFT or VIGS fail to train M1 gunnery skills. Because this research did not evaluate the transfer from these devices to the M1 tank, conclusions regarding transfer to the tank must await further research.

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Appendix A

Summary of Biographical Data

1. Mean Time in service 18.92 mos.   Range 4 mos. to 61 mos.

2. Grade

E-1	3
E-2	4
E-3	13
E-4	4

3. Mean Age 20.29 yrs.   Range 18 yrs. to 23 yrs.

4. Education Level

Less than 12 years	3
High School graduate	18
GED	1
Technical School	0
Some college	2

5. Mean GT Score 98.6   Range 83 to 121

6. Mean Time in Armor 16.71 mos.   Range 4 mos. to 61 mos.

7. Present Crew Position

Drivers	13
Gunners	6
Loaders	3
Other	2

Mean Time in Position 5.83 mos.

8. Number who have previously used a table-top gunnery training device 5
Number who have never used a table-top gunnery training device 19

Appendix B

Biographical Questionnaire

SUBJECT #________________________________

1. Total time in service __________ years __________ months

2. Grade E-_____

3. Age _____ years

4. Educational level. Circle one.

   a. less than 12 years   b. high school grad   c. GED

   d. technical school   e. college (# of years) _____

5. GT Score _____

6. How long have you been in Armor? __________ years __________ months

7. What is your present crew position? _____________________________________

   How long? _______________

8. Have you ever used a table-top tank gunnery training device? Yes No

   If yes, how may times?

   If yes, when did you last use the trainer? __________ months

   What was the trainer? ____

PT 5623

Appendix C

Instructions to Subjects

MK1 VIGS

Today you will be using the MK1 Gunnery Trainer to sharpen your gunnery skills. While the MK1 is designed to present both daylight and thermal scenes, only thermal scenes will be presented during this exercise. You will be trained by engaging approximately 60 targets. As each target is presented, you will hear a fire command. When the fire command is given you should move to the sight and promptly acquire and engage the target presented. However, if you attempt to engage a target before the word "UP" appears on your sight picture, the gun will not fire. Your performance will be measured for each engagement. As in actual combat, both speed and accuracy are important in engaging targets. Each time you fire, you will see where your round hit relative to the target. When you hit a target, an explosion will occur at the target and the target will stop moving. If you fail to hit the target after 35 to 40 seconds, the engagement will end. When the engagement ends, insure that the ammunition select switch is set for SABOT, and wait for the next fire command. Listen carefully to the fire commands and give the appropriate responses by announcing IDENTIFIED when you acquire a target and ON THE WAY when you fire.

As you train on the VIGS, you may ask questions and assistance will be provided as needed. Do you have any questions at this time?

Forget for a moment that you are training on a simulator. Instead imagine that your platoon is part of an M1, M2 Attack Helicopter-equipped brigade which has penetrated the enemy's forward echelons. You are well-behind the enemy's forward-deployed combat forces, where your mission is to attack and generally disrupt the enemy's supply lines and troop reinforcements. Your tank has its full complement of SABOT on board but has limited HEAT rounds and is critically short of machinegun ammunition. A round of SABOT is in the chamber, and a SABOT round will be loaded prior to the start of each engagement. Visibility through the daylight sight is extremely poor due to fog and approaching darkness. Thermal optics are necessary, and your tank commander has told you to use them exclusively.

M1 UCOFT

You will be using the M1 Unit Conduct of Fire Trainer (UCOFT) to sharpen your gunnery skills. The UCOFT presents computer-generated scenes of both day and night gunnery engagements. Following a brief familiarization with the UCOFT controls and engagement techniques, you will be trained on approximately 60 gunnery scenarios.

The UCOFT presents both offensive and defensive scenarios. In the offensive scenarios you shoot with your tank on the move. In the defensive engagements, your tank moves up from behind a berm, stops and then fires while stationary. For the first phase of UCOFT training, all engagements will be defensive; that is, your tank is stationary.

As each target is presented your TC will acquire the target and issue a fire command. When the TC issues the fire command, you should select main gun or machinegun. You will hear the TC command, "driver, move out." You will then use your GPS to identify and engage the target. When you detect the target you should switch the GPS to 10x, lay on and track the target and fire upon the TC's command. Your performance will be measured for each engagement. As in actual combat, both speed and accuracy are important in engaging targets. When you hit a target, a white flash occurs at the target, its normal motion ceases, and it assumes a killed posture. If you miss a target dirt will be kicked up. If you fail to kill the target in the allotted time (18 to 24 seconds), all sights will go black and controls will be inoperative for five seconds to indicate that you were killed. After each engagement, insure that the ammunition select switch is set for SABOT, and wait for the next fire command. Listen carefully to the fire commands and give the appropriate responses by announcing IDENTIFIED when you acquire a target and ON THE WAY when you fire.

As you train on the UCOFT, you may ask questions and your TC and the instructor/operator will provide assistance as needed. Do you have any questions at this time?

Forget for a moment that you are training on a simulator. Instead imagine that your platoon is part of an M1, M2 Attack Helicopter-equipped brigade which has penetrated the enemy's forward echelons. You are well-behind the enemy's forward-deployed combat forces, where your mission is to attack and generally disrupt the enemy's supply lines and troop reinforcements. Your tank has its full complement of SABOT on board but has limited HEAT rounds and is critically short of machinegun ammunition. A round of SABOT is in the chamber, and a SABOT round will be loaded prior to the start of each engagement. Visibility through the daylight sight is extremely poor due to fog and approaching darkness. Thermal optics are necessary, and your tank commander has told you to use them exclusively.

Appendix D

Differential Learning Effects Data

Table D-1
Variances of Gunnery Performance Measures for Two Test Replications

Performance Measure	VIGS Performance REP1	VIGS Performance REP2	UCOFT Performance REP1	UCOFT Performance REP2
Hit Percentage	82.99	90.25	196.56	159.01
First Rnd Percentage	135.72	151.54	160.28	128.14
Azimuth Error	0.76	0.14	1.88	0.25
Elevation Error	0.06	0.04	0.21	0.08
Identification Time	1.23	0.82	6.75	3.60
Opening Time	4.75	4.58	4.33	3.17
Hit Time	3.65	4.28	7.84	4.36
Sys Mgmt Error	0.14	0.40	2.40	0.42

Table D-2
Variance Ratios (First Replication/Second Replication)

Performance Measure	VIGS Performance	UCOFT Performance
Hit Percentage	0.92	1.24
First Rnd Percentage	0.90	1.25
Azimuth Error	5.43	7.52
Elevation Error	1.50	2.63
Identification Time	1.50	1.88
Opening Time	1.04	1.37
Hit Time	0.85	1.80
Sys Mgmt Error	0.35	5.71

Note. Large ratios represent large decreases in variance from the first to the second replication, and are indicative of differential learning.

Table D-3
Group Means of the Differences between First and Second Replication Scores for Low and High Performing Groups

	Means			
	Low Performance	High Performance	t	p>t
VIGS Performance				
First Rnd Hit %	10.85	3.69	1.74	.0957
Azimuth Aiming Error	-1.29	.013	5.30	.0001
Elevation Aiming Error	-.279	-.045	3.04	.0060
Hit Time	-1.56	-0.94	1.29	.2091
UCOFT Performance				
First Rnd Hit %	20.00	11.22	2.04	.0516
Azimuth Aiming Error	-1.98	-0.17	4.43	.0002
Elevation Aiming Error	-0.35	.065	2.14	.0435
Hit Time	-3.49	-0.61	2.59	.0166

Appendix E

Correlations Between Biographical Data and Performance Measures

Table E-1

Education Level, GT Score, and Armor Experience as Predictors of Performance on VIGS and UCOFT

	Biographical Measure		
Performance Measure	Education Level	General Technical (GT) Score	Armor Experience (MOS)
UCOFT Hit Percentage	0.24	-0.13	-0.20
UCOFT First Rnd hits	0.15	-0.15	-0.28
UCOFT Azimuth Aiming Error	-0.29	0.04	0.16
UCOFT Elevation Aiming Error	-0.24	0.30	-0.07
UCOFT Opening Time	-0.24	-0.01	-0.07
UCOFT Hit Time	-.04	0.16	0.00
UCOFT System Management Errors	-0.14	-0.23	-0.02
VIGS Hit Percentage	-0.10	-0.20	-0.17
VIGS First Rnd Hits	-0.10	-0.22	-0.18
VIGS Azimuth Aiming Error	0.23	0.23	-0.01
VIGS Elevation Aiming Error	0.06	0.41	0.28
VIGS Opening Time	0.12	0.00	-0.30
VIGS Hit Time	0.11	0.08	-0.23
VIGS System Management Errors	0.12	0.05	-0.07